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traveling from the site of injury, but no cytokine-like proteins have been isolated from insects yet. In snails and other invertebrates, anti–interleukin 1 antibody cross-reacts with hemolymph components, but these components have not yet been identified.

Transcription factors. Insect antibacterial peptide expression is primarily controlled at the transcriptional level, another mechanism shared by vertebrates and invertebrates. A transcription factor regulating immune gene induction in the moth *Hyalophora cecropia* (cecropia immune factor) was found to be similar to NF-κB, a mammalian transcription factor important in regulating many genes in inflammation and the immune response. NF-κB consists of Rel proteins (Rel refers to a family of transcription factors including oncogenes and a gene from the reticular endotheliosis virus, which gave the family its name). NF-κB's activity is regulated by an inhibitory factor, IκB, which holds NF-κB in the cytoplasm. Upon activation, IκB is degraded, while active NF-κB moves into the nucleus.

Similar Rel factors have been identified in the flesh fly and in *Drosophila.* Dorsallike immune factor binds to the cecropin promoter and activates cecropin transcription in cell transfection assays. This factor is clearly a key element in antibacterial peptide induction, and the similarities between dorsallike immune factor and NF-κB in function (and presumably regulation) are compelling. Another Rel protein, Dorsal, plays a role in immunity; it binds to the diptericin promoter and activates gene transcription in cell transfection assays. Recently, a third *Drosophila* Rel protein, the gene *Relish,* was discovered. *Relish* contains IκB-like domains, similar to several mammalian NF-κB proteins. One of the NF-κB domains of these proteins has been shown to have IκB-like activity, and the inhibitory domain must be proteolytically removed to generate active NF-κB. Whether this is also the case with *Relish* is not yet known.

It is striking that Rel factors are key regulators of immune responses in both vertebrates and invertebrates. Even though effector pathways have diverged—the activation of inflammatory genes and immunoglobulins in vertebrates versus antimicrobial peptides in invertebrates—both groups use similar transcription factors to induce gene synthesis in response to infection. This clearly shows that Rel factor involvement in immunity is primordial in origin. *SEE INFLAMMATION.*

For background information *SEE ANIMAL VIRUS; ANTIBODY; ANTIGEN; IMMUNITY; PHAGOCYTOSIS* in the McGraw-Hill Encyclopedia of Science & Technology.

Mitchell Dushay

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Irrigation (agriculture)

Recent inventories suggest that about 15–17% of the world's cultivated cropland is irrigated. About 40% of these acres were developed after 1960 to meet the food and fiber needs of the world's population, which grew rapidly after World War II in response to medical and hygienic advances. The lack of significant new water resources and the cost of developing present ones have caused irrigated acreage to plateau at around 6×10^8 acres (2.4×10^8 hectares) since the late 1980s. Recent advances in irrigation include the further development of sprinkler technology.

Impact on global harvest. The increase in irrigated acres from about 1960 through the 1980s, coupled with advanced agronomic practices and improved crop varieties, became known as the green revolution, and provided a brief period of global plenty. Despite the large increases in world population, food surpluses rose to some of their highest levels in recent history. Famine-prone nations such as India became exporters of grain. Slowing of irrigation development since 1980 has been an important factor in the renewed decline in world food reserves.

Earth's irrigated acres (one-sixth of all cropland) provide about one-third of the annual harvest, making irrigation more than twice as productive as rain-fed agriculture. The monetary value of irrigation's harvest is even greater than one-third the total. More importantly, one-third of the world's food crop harvest comes from a mere 1.25×10^8 acres (5×10^7 ha) of irrigated land, despite the fact that irrigated agriculture generally occurs on relatively poor soils.

Irrigated agriculture's efficiency and elevated monetary return stem mainly from two factors: First, irrigation generally results in higher-quality commodities because of its ability to better regulate inputs and prevent stresses than rain-fed agriculture. Second, the ability to reduce risk of stress, disease, and input inefficiencies often allows commercial production of crops having higher intrinsic monetary value.

In fact, on a global scale, most irrigated lands contribute positively to agricultural sustainability. Arid soils typically have low organic matter contents and high base saturation (a high ratio of adsorbed nutrient cations to hydrogen cation). Thus, arid soils seldom require liming to maintain favorable pH levels. They usually need less potassium fertilizer and lower soil-applied herbicide application rates for comparable weed control. The arid climate associated with most of irrigated agriculture not only maximizes photosynthesis but also in many cases translates to lower disease and pest pressures, often reducing required pesticide inputs for profitable production.

Another important aspect of irrigation is the role it plays in food security. As populations continue increase, not only does the amount of produc needed to meet human nutrition and fiber requirements increase, but so does the need for reliable production levels. Irrigated agriculture has proven less subject to the variability of climate and water supply than rain-fed agriculture. In properly managed irrigated schemes the impact of a short-term or even season-long drought can be mitigated by use of the water stored in reservoirs and groundwater aquifers. In rain-fed agriculture, droughts commonly cause serious yield reduction and sometimes complete crop failure.

Impact on environment. If all the world's irrigated land were taken out of production, it would require the cultivation of new land equal to more than 36 times the farmed area of Iowa to replace irrigated agriculture's contribution to Earth's harvest (a conservative estimate based on average production). Even if the land currently irrigated were left in rain-fed production, the extent of new land required to fill the production void would not be significantly reduced, for two reasons: First, the level of food and fiber production on land currently irrigated would be much lower than average rain-fed production, since most irrigation occurs in arid environments. Second, the world's choicest arable land is already in production. The productivity of the remaining lands, with their natural soil-climate associations, would not equal the existing mean rain-fed cropland base. In this way the use of irrigated agriculture currently allows more than 1.2×10^9 acres (4.8×10^8 ha) of Earth's rainforests, grasslands, ranges, and marshes to remain in undisturbed natural ecosystems.

In addition, irrigated agriculture's efficiency and concentration in arid and semiarid ecosystems have minimized species loss by limiting the need to clear more densely speciated environments (for example, rainforests) for agricultural development.

The most frequent criticism of irrigation focuses on disruption of natural ecosystems and species (or even cultural) displacement. Yet these outcomes also result from land management for rain-fed agricultural development, and usually occur on a larger scale because of the lower efficiencies. Critics of irrigation development frequently point to elevation of water tables and soil salinization as inherent problems. In reality, these problems usually result not from inherent failures of irrigated agriculture but from improper irrigation development. Modern irrigation design recognizes the need for adequate natural or artificial soil drainage and for application of adequate amounts of water to overcome salt accumulation.

It is worth noting that development of water resources has often had significant benefits beyond environmental ones. Water reservoirs and waterways provide hydropower, flood control, recreational resources, transportation, and fishing resources.

R. E. Sojka

Sprinkler technology. Sprinkler irrigation was developed to overcome many of the inherent limitations of earlier irrigation methods that relied on the soil surface to convey and distribute water to crops. Sprinkler application devices have evolved from simple orifices to a variety of nozzles designed to provide flexible and efficient water distribution over a wide range of soil and topographical conditions. Even though sprinkler irrigation requires energy to pressurize the system, the additional energy costs are largely offset by improved crop quality, reduced water applications, and labor savings. The gross amount of water applied is reduced because the applications are more uniform. Improved application uniformity allows smaller amounts of water to be applied more frequently, thus maintaining more favorable moisture conditions in the root zone so as to decrease water stress and improve the quality and yield of crops.

Technology development. Water droplets from sprinklers are subject to wind drift and evaporation. Contrary to the general perception that evaporation losses are significantly increased with sprinklers, recent energy budget studies have shown that maximum evaporation losses probably do not exceed 5% of the applied water. The effects of wind drift and distortion of application uniformity are more significant and have encouraged the development of improved nozzles that create larger droplets, which are less susceptible to wind drift. Size and spatial distribution of water droplets can be measured with laser technology; such studies are used to design and select sprinklers best suited for the operating conditions at a site.

Microprocessor technology is being used to improve the reliability and versatility of large mechanically moved irrigation systems. With improved control capabilities, producers are adopting innovative crop production practices that improve crop quality while conserving valuable water resources. Judicious application to meet crop water needs reduces leaching, which can transport valuable nutrients below the root zone as well as degrade water quality of the leachate that may eventually become part of the groundwater supply. Sprinklers may also be used in conjunction with drip irrigation systems to leach accumulated salts below the root zone during the nongrowing season or to germinate sensitive shallow-rooted crops.

Application of chemicals. Sprinkler equipment has been adapted to apply chemicals necessary for crop production through the irrigation system, a practice called chemigation. Fertilizers, herbicides, insecticides, fungicides, and growth regulators can be injected into the water as it is applied to the crop. Fertilizers that are susceptible to leaching, such as nitrate nitrogen, can be more effective and less likely to be leached when applied through the irrigation system as the crop needs it. Herbicides are the most frequently applied pesticide, and water applied simultaneously with the herbicide is usually necessary to activate the chemical. Fungicides applied with irrigation water have been demonstrated to be effective in controlling soil-borne diseases in a variety of vegetable crops. The advantages of chemigation are improved control of timing and uniformity of chemical applications, resulting in reduced chemical application amounts and costs. Food quality is improved by more timely applications of chemicals, while the environmental hazards of leached nutrients and chemicals degrading ground-water quality are reduced.

Low-pressure and low-volume sprinklers. New sprinkler applicators requiring lower pressures have been developed to combat rising energy costs. Assuming equal application uniformity and irrigation performance, low-pressure sprinklers require less energy than earlier high-pressure ones. For row crops, an irrigation system known as the low-energy precision application was developed to make more efficient use of limited water supplies as well as to maximize effectiveness of natural precipitation. Low-pressure nozzles are suspended from the overhead pipes of center-pivot or linear-move systems to a height of 15–18 in. (38–46 cm) above the soil surface. Small dikes every 4–6 ft (1.2–1.8 m) are created in each furrow to catch the applied water and allow it to infiltrate where applied.

Low-volume sprinklers that operate at low pressures, such as plastic microspray nozzles, have been developed primarily for use on tree crops in soils with low water-holding capacities and with limited ability to spread water by capillary action. The advantages of microsprays are low cost, a smaller volume of water delivered at lower pressures, and the ability to apply fertilizers and chemicals around the trees for maximum effectiveness.

Modification of microclimate. In fruit-producing areas susceptible to freezing temperatures, sprinklers can be used to modify the microclimate and protect the fruit crop from frost. When water is applied at a very low rate during freezing temperatures, heat is released when the water freezes, preventing damage to the plant tissue itself. Good management is required so as to operate sprinklers to achieve protection without causing ice damage to the trees.

Another example of microclimate modification is using sprinklers for evaporative cooling of tree or vegetable crops. When temperatures are higher than desirable, crops can be sprinkled frequently to create a cooler environment, which delays bloom and bud formation, thus reducing the likelihood of freeze damage as well as improving fruit yield. During critical growth periods, extremely high temperatures can cause detrimental stress in the plants. Water applied with sprinklers evaporates, cooling the temperature in the vicinity of the crop and reducing the water and temperature stress on the crop.

Wastewater reuse. Although the concept of using sprinklers to spread wastewater on cropland is not new, there is increased interest in using sprinkler irrigation as an environmentally sound disposal method that recognizes the nutrient value of wastewater as a resource. Especially in water-short areas, wastewater is reclaimed and used for irrigating cash crops as well as public areas such as parks and golf courses. Sprinkler irrigation systems can also apply sludge slurry to reclaim old mined or severely nutrient-deficient areas. The main benefits of sludge application are the release of nutrients for crop growth and the improved physical condition of the soil from increased organic matter. The main difficulty is the inability to match the available nutrients with the crop's nutritional needs, which can cause a detrimental buildup of certain nutrients and heavy metals. Recent work has focused on determining long-term, environmentally sound disposal rates.

Prospects. The trend for increased sprinkler irrigation is likely to continue because of labor savings and the ability to apply water more uniformly. Efforts to improve the sprinkler's versatility will continue as long as there are economic incentives to conserve water, energy, and nutrient resources.

For background information SEE ECOSYSTEM; IRRIGATION (AGRICULTURE); SOIL CHEMISTRY; WATER CONSERVATION in the McGraw-Hill Encyclopedia of Science & Technology.

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Language processing

Only humans communicate through speech: both talking (speech production) and listening (speech perception) involve the brain as much as the tongue and the ear. It is not known which neural circuits in the human brain interpret changes in sound pressure at the eardrums to distinguish speech and, more importantly, differentiate the sounds as a request, a demand, or a statement, and which circuits turn an idea into a meaningful utterance, either spoken or signed. Neuroscientists have not determined how many different brain areas are involved, what each does (or should do), and in what order each task is performed. Practically, no cognitive scientist could possibly build a robot with speech capabilities equal to that of a human if it had to be done on the basis of current knowledge about speech and the brain. SEE BRAIN.

The role of the brain. The human brain is a bilaterally symmetrical structure, interconnected by two main bridges of neurons. Neuropsychological research has demonstrated that an adult with left hemisphere damage is likely to have some difficulty in speaking (or signing) and in making sense of what is said or signed (a condition called ap-